

Comparison of Hourly Dst and One-Minute SYM/H Indices During the May 2024 Extreme Geomagnetic Storm

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Abstract

Geomagnetic indices are fundamental tools for characterizing the intensity and temporal evolution of geomagnetic storms (GSs). However, differences in temporal resolution can influence the representation of rapid storm-time variations and the determination of storm minima. In this study, the conventional hourly Disturbance Storm Time (Dst) index and the Symmetric H-component (SYM/H) index were comparatively analyzed during the extreme geomagnetic storm of 10–12 May 2024. The event was selected as one of the strongest GSs of recent years. The analysis focused on the complete storm evolution and a detailed examination of the main phase. Both indices consistently reproduced the major phases of the storm, including the rapid main-phase decrease, maximum geomagnetic disturbance, and subsequent recovery. However, the higher temporal resolution of SYM/H revealed rapid short-duration fluctuations that were not resolved in the hourly Dst data. The minimum SYM/H value of -518 nT occurred at 02:14 UT on 11 May 2024, whereas the minimum Dst value of -406 nT occurred at 02:00 UT. These differences demonstrate the influence of temporal resolution on the observed timing and magnitude of intense geomagnetic disturbances. The results indicate that Dst and SYM/H provide complementary information, with one-minute SYM/H data offering significant advantages for investigating rapid storm-time variations and the detailed temporal evolution of intense geomagnetic storms.

Keywords: Geomagnetic storm; Dst index; SYM/H index; temporal resolution; May 2024 storm.

1. Introduction

GSs are major disturbances in the Earth's magnetosphere caused by enhanced interaction between the solar wind and the geomagnetic field. Their intensity and temporal evolution are commonly investigated using geomagnetic indices derived from ground-based magnetometer observations. These indices provide important information about the development and intensity of storm-time geomagnetic disturbances (Gonzalez et al., 1994; Gonzalez et al., 1999). The Dst index, introduced by Sugiura (1963), is one of the most widely used indices for measuring GS intensity. It represents variations in the horizontal component of the Earth's magnetic field at low latitudes and is commonly used to characterize the development of the storm-time ring current (Burton et al., 1975; Daglis et al., 1999). The conventional Dst index is generally available at an hourly temporal resolution. The SYM/H index is a high-temporal-resolution geomagnetic index that represents the symmetric disturbance in the horizontal

component of the Earth's magnetic field. It is derived from ground-based magnetometer observations and provides information about storm-time geomagnetic variations associated with magnetospheric current systems (Iyemori, 1990; Iyemori & Rao, 1996). Unlike Dst, SYM/H is available at a temporal resolution of one minute. Although Dst and SYM/H describe similar large-scale geomagnetic disturbances, their different temporal resolutions can influence the representation of storm-time variations. Rapid changes occurring within an hour may not be clearly resolved in hourly Dst data but can be identified in the one-minute SYM/H index. A direct comparison by Wanliss and Showalter (2006) showed that Dst and SYM/H generally exhibit similar overall storm evolution, while SYM/H provides additional information about short-timescale variations. The temporal resolution of geomagnetic indices is particularly important during intense storms, when rapid changes in the geomagnetic field can occur during the main phase. While hourly Dst data are useful for describing the general evolution and intensity of a GS, minute-resolution SYM/H data can provide more detailed information about its short-term variations. Therefore, the present study compares the hourly Dst index with the one-minute SYM/H index during the extreme GS of 10–12 May 2024. The comparison focuses on the complete storm evolution and the detailed main phase to investigate the influence of temporal resolution on the observed geomagnetic variations.

2. Data and Methodology

The present study considers the extreme GS that occurred during 10–12 May 2024. This storm was selected because it was one of the strongest geomagnetic disturbances of recent years and provides an appropriate event for comparing geomagnetic indices with different temporal resolutions. Two geomagnetic indices were used: the hourly Dst index and the one-minute SYM/H index. The Dst data were obtained from the [NASA OMNIWeb hourly data explorer](#), which provides hourly-averaged data including the Dst index. The one-minute SYM/H data were obtained from the [NASA OMNIWeb High-Resolution OMNI database](#), which provides SYM/H at one-minute resolution. ([OMNIWeb Service](#)) Both indices were selected for the same period, from 10 to 12 May 2024, and plotted together. The analysis was performed using two figures: the first compares the complete storm evolution, while the second focuses on the main phase to examine rapid variations and differences in the timing and magnitude of the storm minimum. This comparison was used to investigate the effect of hourly and minute temporal resolution on the representation of GS variations.

3. Results and Discussion

3.1. Full storm evolution

Figure 1 presents the complete evolution of the May 2024 GS from 10 to 12 May 2024 using the hourly Dst and one-minute SYM/H indices. Both indices show a similar overall pattern of storm development, including the relatively quiet pre-storm period, the rapid decrease during the main phase, the maximum geomagnetic disturbance, and the subsequent recovery phase. This general agreement is consistent with the comparative study of Wanliss and Showalter (2006), who reported that Dst and SYM/H generally exhibit similar large-scale storm-time behavior.

During the initial period, both indices remained at relatively low disturbance levels. Subsequently, a rapid decrease was observed, indicating the development of an intense geomagnetic disturbance. The decrease in the indices during the main phase is associated with enhanced storm-time magnetospheric currents and the resulting depression of the horizontal component of the geomagnetic field. The general

development of the main and recovery phases is consistent with the classical description of GS evolution discussed by Gonzalez et al. (1994) and the storm-time Dst behavior described by Burton et al. (1975).

The hourly Dst index reached a minimum value of $Dst_{min}[f_0] = -406$ nT

In comparison, the one-minute SYM/H index reached a more negative minimum value of $SYM/H_{min}[f_0] = -518$ nT

Although the minimum magnitudes are different, both indices clearly identify the May 2024 event as an extremely intense GS. The more negative SYM/H value provides a detailed representation of the rapid magnetic-field depression occurring during the main phase. The difference between the minimum values can be partly explained by the different temporal resolutions of the two indices. The hourly Dst index represents geomagnetic variations at an hourly timescale, whereas the one-minute SYM/H index can resolve short-duration variations occurring within individual hourly intervals.

As demonstrated by Wanliss and Showalter (2006), SYM/H and Dst generally show similar large-scale variations, but the higher temporal resolution of SYM/H provides additional information regarding rapid storm-time changes. Consequently, short-duration decreases or fluctuations in the geomagnetic field may be more clearly represented by SYM/H than by hourly Dst data. The detailed variations visible in the SYM/H profile in Figure 1 therefore provide information that cannot be obtained from the hourly Dst time series alone.

However, the difference between Dst and SYM/H should not be attributed only to temporal resolution. Wanliss and Showalter (2006) also noted that the two indices differ in their calculation procedures and data processing. Therefore, differences in their instantaneous magnitudes can occur even when they describe the same overall storm evolution.

Overall, Figure 1 demonstrates that both indices provide a consistent representation of the complete development of the May 2024 GS. The Dst index clearly describes the general evolution and intensity of the event, whereas the one-minute SYM/H index reveals additional short-timescale variations. This result highlights the importance of high-temporal-resolution geomagnetic data for investigating the detailed evolution of intense storms.



Figure 1. Full evolution of the May 2024 GS from 10–12 May 2024, comparing the hourly Dst index and one-minute SYM/H index. Both indices show the overall storm evolution, while the higher temporal resolution of SYM/H reveals more detailed variations.

3.2. Main-phase comparison

Figure 2 provides a detailed view of the main phase of the May 2024 GS on 11 May 2024. The comparison between the hourly Dst and one-minute SYM/H indices clearly demonstrates the importance of temporal resolution when investigating the rapid evolution of an intense GS. While both indices show a pronounced decrease during the main phase, the detailed structure of the variation is more clearly represented by the one-minute SYM/H data. The hourly Dst index indicates the general progression of the geomagnetic disturbance through successive hourly measurements. It clearly shows the rapid development of the storm and the strong depression of the geomagnetic field during the main phase. However, because Dst is available at hourly resolution, variations occurring within individual hourly intervals cannot be separately identified. In contrast, the one-minute SYM/H index provides a much more detailed representation of the geomagnetic field and reveals substantial short-term fluctuations during the same period. The rapid decrease observed during the main phase is characteristic of an intense GS and reflects enhanced magnetospheric disturbances. The general storm-time evolution observed in Figure 2 is consistent with the description of GS development given by Gonzalez et al. (1994) and the relationship between solar-wind conditions and the evolution of the Dst index described by Burton et al. (1975). However, the present comparison shows that the detailed timing and magnitude of the rapid variations depend on the temporal resolution of the geomagnetic index.

The minimum Dst value occurred at

$$\text{Dst}_{\min} = -406 \text{ nT}$$

at 02:00 UT on 11 May 2024, whereas the one-minute SYM/H index reached a minimum value of

$$\text{SYM/H}_{\min} = -518 \text{ nT}$$

at 02:14 UT on 11 May 2024.

Thus, the SYM/H minimum occurred approximately 14 minutes after the hourly timestamp corresponding to the minimum Dst value. In addition to the difference in timing, the SYM/H index recorded a stronger instantaneous geomagnetic depression. This demonstrates that the detailed storm-time magnetic-field variations can be more precisely resolved when using minute-resolution data. The difference between the minimum values should not necessarily be interpreted as a disagreement between the two indices. Instead, it reflects differences in temporal resolution and, potentially, differences in the procedures used to derive the indices. Wanliss and Showalter (2006) showed that Dst and SYM/H generally exhibit similar large-scale storm-time behavior despite differences in their construction and temporal resolution. Their study emphasized that the major advantage of SYM/H is its ability to provide a high-resolution representation of rapid geomagnetic variations. The detailed SYM/H curve in Figure 2 contains several minute-to-minute fluctuations that are not represented in the hourly Dst time series. An hourly value provides information about the general geomagnetic disturbance during an hour, whereas the one-minute SYM/H data can preserve shorter variations occurring during that interval. Therefore, the SYM/H index provides additional information regarding the detailed temporal structure of the main phase.

This characteristic is particularly important during extreme GSs, when the magnetic field can change substantially over short timescales. Studies of high-resolution geomagnetic disturbances have shown the importance of investigating storm-time variations at appropriate temporal resolutions, particularly when

examining rapid changes in magnetospheric current systems (Iyemori & Rao, 1996; Wanliss & Showalter, 2006). The present results therefore confirm that the hourly Dst and one-minute SYM/H indices are complementary rather than competing measures. The hourly Dst index effectively describes the general intensity and large-scale evolution of the May 2024 storm, while the one-minute SYM/H index provides a more detailed representation of rapid fluctuations and the precise evolution of the main phase. Overall, Figure 2 demonstrates that the use of one-minute SYM/H data is particularly valuable when investigating the detailed temporal evolution of intense GSs. The ability of SYM/H to resolve the stronger and more precisely timed geomagnetic depression highlights the importance of temporal resolution in studies focused on rapid storm-time variations.

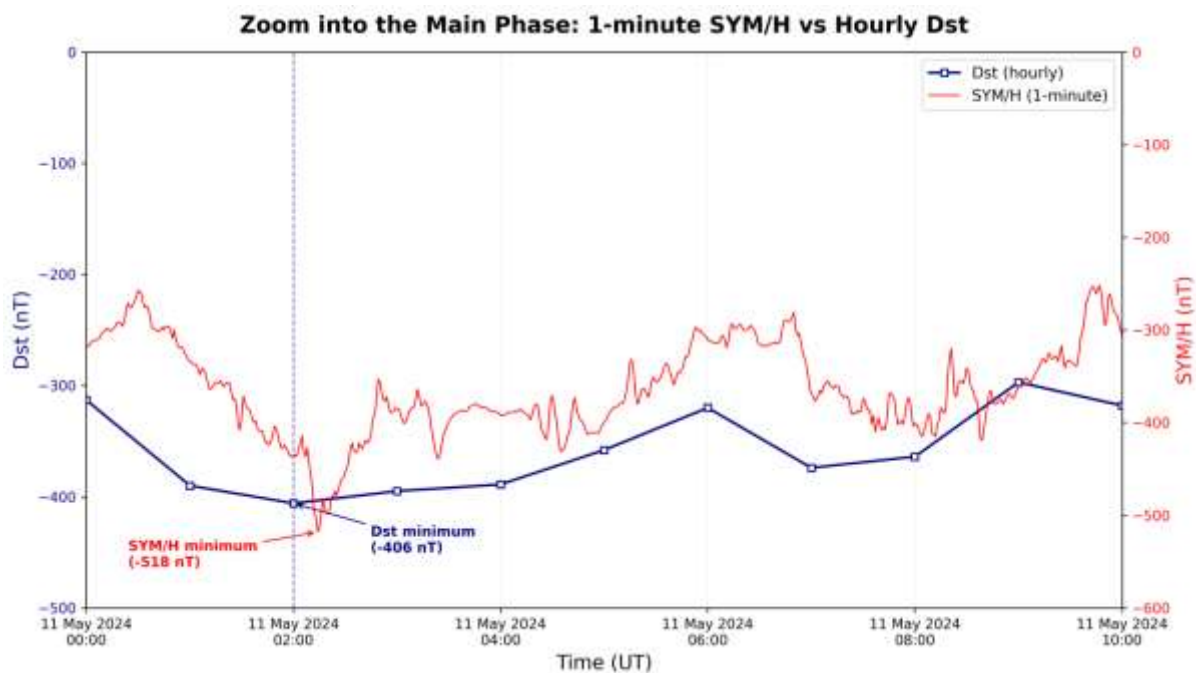


Figure 2. Zoomed view of the main phase of the May 2024 GS, comparing the one-minute SYM/H index with the hourly Dst index. The higher temporal resolution of SYM/H captures rapid fluctuations and identifies the storm minimum at a more precise time.

4. Comparison between Dst and SYM/H

The comparison between the two indices can be summarized as follows:

Parameters	Dst	SYM/H
Temporal resolution	Hourly	1 minute
Storm evolution	Clearly represented	Clearly represented
Rapid fluctuations	Limited	Clearly resolved
Minimum during May 2024 storm	-406 nT	-518 nT
Minimum timing	02:00 UT	02:14UT
Main advantage	Long-term storm characterization	Detailed short-term storm evolution

The results indicate that the two indices are generally consistent in describing the large-scale evolution of the GS. However, the SYM/H index provides substantially greater temporal detail.

6. Conclusion

This study compared the hourly Dst index with the one-minute SYM/H index during the extreme GS of 10–12 May 2024. The comparison was performed using the complete storm evolution and a detailed examination of the main phase.

The major conclusions are:

1. Both Dst and SYM/H successfully reproduced the overall evolution of the May 2024 GS.
2. The hourly Dst index reached a minimum value of -406 nT, while the one-minute SYM/H index recorded a more negative minimum of -518 nT.
3. The Dst minimum occurred at 02:00 UT, whereas the SYM/H minimum occurred at 02:14 UT, demonstrating the ability of minute-resolution data to determine storm-time variations more precisely.
4. The one-minute SYM/H index revealed rapid fluctuations during the main phase that were not visible in the hourly Dst data.
5. The results demonstrate that temporal resolution is important when investigating intense GSs.

These results demonstrate that temporal resolution significantly influences the observed magnitude and timing of intense geomagnetic disturbances. While hourly Dst data are suitable for describing the general intensity and evolution of a GS, the one-minute SYM/H index provides a more detailed representation of rapid storm-time variations. Therefore, Dst and SYM/H should be considered complementary indices, with high-resolution SYM/H data being particularly valuable for investigating the detailed temporal evolution of intense GSs.

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References

2. Burton, R. K., McPherron, R. L., & Russell, C. T. (1975). An empirical relationship between interplanetary conditions and Dst. *Journal of geophysical research*, 80(31), 4204-4214.
3. Daglis, I. A., Thorne, R. M., Baumjohann, W., & Orsini, S. (1999). The terrestrial ring current: Origin, formation, and decay. *Reviews of Geophysics*, 37(4), 407-438.
4. Gonzalez, W. D., Joselyn, J. A., Kamide, Y., Kroehl, H. W., Rostoker, G., Tsurutani, B. T., & Vasyliunas, V. M. (1994). What is a geomagnetic storm?. *Journal of Geophysical Research: Space Physics*, 99(A4), 5771-5792.
5. Gonzalez, W. D., Tsurutani, B. T., & Clúa de Gonzalez, A. L. (1999). Interplanetary origin of geomagnetic storms. *Space Science Reviews*, 88(3), 529-562.
6. Iyemori, T. (1990). Storm-time magnetospheric currents inferred from mid-latitude geomagnetic field variations. *Journal of geomagnetism and geoelectricity*, 42(11), 1249-1265.
7. Iyemori, T., & Rao, D. R. K. (1996, June). Decay of the Dst field of geomagnetic disturbance after substorm onset and its implication to storm-substorm relation. In *Annales Geophysicae* (Vol. 14, No. 6, pp. 608-618). Göttingen, Germany: Springer Verlag.
8. Sugiura, M. (1963). *Hourly values of equatorial Dst for the IGY* (No. NASA-TM-X-55238).

9. Wanliss, J. A., & Showalter, K. M. (2006). High-resolution global storm index: Dst versus SYM-H. *Journal of Geophysical Research: Space Physics*, 111(A2).